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Specification

1. Title of the Invention

External circuit connection structure for a liquid crystal panel

2. Scope of Claims

(1) An external circuit connection structure for a liquid crystal panel and an external circuit, characterized by comprising: an external circuit connection electrode connected to a drive electrode for a liquid crystal panel with a ferroelectric liquid crystal and arranged on a substrate of the liquid crystal panel; an external circuit electrode connected to an external circuit and arranged on a substrate of the external circuit; and a cured body arranged between the external circuit connection electrode and the external circuit electrode and composed of a thermosetting resin dispersedly containing conductor particles.

(2) An external connection structure for a liquid crystal panel according to claim 1, wherein the ferroelectric liquid crystal has a chiral smetic phase which is formed by gradually cooling down from an isotropic phase.

(3) An external connection structure for a liquid crystal panel according to claim 2, wherein the thickness of the ferroelectric liquid crystal having the chiral smetic phase is set to such a thickness that the spiral structure peculiar to the chiral smetic phase is resolved when there is no electric field.

(4) An external circuit connection structure for a liquid crystal panel, wherein the

chiral smectic phase is either a chiral smectic C phase or a chiral smectic H phase.

3. Detailed Description of the Invention

[Field of the Invention]

This invention relates to an electrical connection structure between a liquid crystal panel equipped with a ferroelectric liquid crystal and an external control circuit.

[Prior Art]

Up to now, as a method of connecting an FPC (flexible printed circuit) and a liquid crystal panel with each other, the method of by performing thermocompression bonding of an anisotropic conductive film which is composed of an insulating resin dispersedly containing conductor particles is well known.

By the way, recently, a ferroelectirc liquid crystal element with memory characteristics has been disclosed in U.S. Pat. No. 4,367,924 by Clark et al., etc. This ferroelectric liquid crystal element is applicable to a display panel utilizing the multiplexing drive proposed by Kanbe et al. in U.S. Pat. No. 4,655,561, etc., from which a high definition display on a wide liquid crystal screen by the liquid crystal elements is to be expected.

As clearly shown by Okada et al. in U.S. Pat. No. 4,639,089, etc., in the above-mentioned ferroelectric liquid crystal element, when a monodomain orientation state is to be formed, it is required to gradually cool down (ca. 5°C /hr.) from an isotropic phase on the high temperature side until a chiral smectic phase is attained after going through a cholesteric phase and a smectic A phase. In the case where rapid cooling down or heating is conducted to attain a chiral smectic phase or an isotropic phase, a monodomain orientation can not be obtained.

Therefore, when electrically connecting a liquid crystal panel provided with the ferroelectric liquid crystal with an external control circuit by thermocompression bonding

described above, there is involved a partially or entirely rapid heating of the liquid crystal element. After this thermocompression is canceled, the heated element is rapidly cooled. Accordingly, when the chiral smectic phase is regained, there is a case where no monodomain orientation state is generated. Such disturbed orientation state may be restored to the earlier monodomain state by a re-orientation process. This, however, involves some problems: for example, employment of an anisotropic conductive adhesive mainly composed of a conventional thermoplastic resin during re-orientation will increase the connection resistance, as will be described later.

[Summary of the Invention]

It is an object of this invention to provide an external circuit connection structure for a liquid crystal panel which is free from the above problems and particularly one which offers a satisfactory electrical connection without disturbing the orientation of the ferroelectric liquid crystal.

The external circuit connection structure for a liquid crystal panel in accordance with this invention is characterized by including an external circuit connection electrode connected to a drive electrode for a liquid crystal panel with a ferroelectric liquid crystal and arranged on a substrate of the liquid crystal panel, an external circuit electrode connected to an external circuit and arranged on a substrate of the external circuit, and a cured body arranged between the external circuit connection electrode and the external circuit electrode and composed of a thermosetting resin dispersedly containing conductor particles.

[Detailed Description of the modes of the Invention]

Hereinbelow, the present invention will be described in accordance with the embodiments. FIG. 1 is a plan view of the connection structure in accordance with this invention. FIG. 2 is a sectional view of the same. The connection structure shown in FIGS.

1 and 2 includes an anisotropic conductive adhesive 11 which consists of a film made of a thermosetting resin dispersedly containing conductive particles and which is capable of forming a cured body under a predetermined thermosetting condition. Metal or alloy particles such as Ni, Au, Ag, solder, etc. or spherical resin particles coated with Au, Ni, etc. may be employed as the conductor particles with satisfactory conductivity. Further, the spherical resin particles having a coefficient of linear expansion that is about the same as that of the thermosetting resin may be used. These conductors are contained by 0.5 to 50, and preferably 5 to 20, parts by weight per 100 parts by weight of the solid portion of the thermosetting resin, and their average particle diameter is 5 to 50 μm, preferably 10 to 30 μm.

Further, as the thermosetting resin to be employed in the present invention, a thermosetting epoxy adhesive, a thermosetting silicon resin, a thermosetting polyimide resin, etc. may be employed.

The above-mentioned anisotropic conductive adhesive 11, is arranged between an external circuit connection electrode 15 led out from a liquid crystal drive electrode wired on a substrate 141 of a liquid crystal panel 14 (for example, a scanning electrode, signal electrode.) and an external circuit electrode 13 wired on a film carrier tape 12 and cured under a predetermined pressurizing condition and curing condition. When this anisotropic conductive adhesive 11 contains a thermosetting resin as the main component, the curing process can be conducted by application of heat by means of a heat tool 16.

The heat tool 16 may be formed from a metal or an alloy with high resistance such as molybdenum and stainless steel. To this heat tool 16 is connected a heating power source 17. The heating power source feeds the heat tool 16 with a voltage of 50 to 500V, preferably 80 to 200V, and a current of 0.1 to 10A, preferably 1 to 5A. Further, time for conducting the thermocompression may be on the order of few seconds.

Further, when the above anisotropic conductive adhesive 11 is in a paste-like state, it may be coated by printing, etc., or used in the form of a half-cured film.

FIG. 3 show graphs illustrating the effects of this embodiment, of which FIG. 3(a) shows the re-orientation process temperature of the ferroelectric liquid crystal element; FIG. 3(b) shows the connection resistance values during the re-orientation process of a mounting structure other than that of the present invention, that is, an anisotropic conductive adhesive employing a thermoplastic resin (resin composed of styrene-butadiene copolymer (50 parts by weight) and a terpene phenol resin (50 parts by weight) dispersedly containing 10 parts by weight of conductor particles composed of high accuracy curing spherical resin particles, EPOSTAR-GP-90 (by NIPPON SHOKUBAI KAGAKU KOGYO CO., LTD.), which are coated with Au); FIG. 3(c) shows the connection resistance values during the re-orientation process of a mounting structure of the present invention (100 parts by weight of a thermosetting epoxy resin with 10 parts by weight of the above-mentioned conductors dispersed therein).

As shown in FIG. 3, heating was conducted from room temperature T_1 (ca. 23ºC) to the re-orientation process temperature T_2 (80ºC), and then a gradual cooling down for about two hours was effected from time t_1 to time t_2. In the case of a mounting structure other than that of the present invention, the initial connection resistance value R_1 (ca. 2Ω) rose up to R_2 (ca. 10 Ω) in the 80ºC atmosphere. After the gradual cooling down, the initial connection resistance value became R_3 (ca. 3 Ω) at room temperature T_1 (23ºC). This may be attributable to the difference in the coefficient of linear expansion between the thermoplastic resin, the glass substrate of the liquid crystal element and the film carrier tape as well as to the softening of the thermoplastic resin due to the re-orientation process temperature, which reduces the adhesive strength thereof, so that the distance of the gap between the connection

electrode of the liquid crystal element and that of the film carrier tape is enlarged, resulting in a reduced contact area and reduced contact particles, contributing to the electrical connection.

In the case of this embodiment of this invention, the initial connection resistance value R_1 (ca. 2 Ω) was raised to R_2 (ca. 3 Ω) in the 80ºC atmosphere. However, after a gradual cooling down for about two hours from time t_1 to time t_2 the value became R_3 (ca. 2 Ω), a value approximately equal to the initial resistance value R_1 at room temperature T_1 (23°C). The slight increase in the connection resistance value in the 80ºC atmosphere and its return to the initial connection resistance value after the gradual cooling down to room temperature may be attributable to the expansion and contraction of the thermosetting resin

Thus, it has been proved that the present invention involves no increase in the connection resistance of the anisotropic conductive adhesive even after a re-orientation process is performed for a ferroelectric liquid crystal whose orientation state is disturbed (a process for restoring any disturbed orientation in a ferroelectric liquid crystal caused by rapid cooling and heating, in which the liquid crystal concerned is reheated until it regains an isotropic phase and cooling it down as described above to thereby reproduce an earlier monodomain orientation state).

The above-mentioned external circuit electrode 13 wired on the film carrier tape 12 is electrically connected to an IC 18 provided as an external control circuit. Further, the IC 18 is connected to the external circuit electrode 13 on the film carrier tape 12 by means of a bonding member 19, the surrounding portion of which is protected by an adhesive 20.

The bistable liquid crystal which may be used in this invention should most preferably be a ferroelectric chiral smectic liquid crystal. The most suited may be a chiral smectic C phase (SmC*) or H phase (SmH*) liquid crystal. Such ferroelectric liquid crystals are described in "Le Journal de Physic Letter", vol. 36 (L-69), the 1975 issue of "Ferroelectric

Liquid Crystals", "Applied Physics Letters", vol 36 (No. 11), the 1980 issue of "Submicron Second Bistable Electroopitc Switching in Liquid Crystal", the 1981 issue of "Solid State Physics", 16 (141), (Liquid Crystal), U.S. Pats. Nos. 4,561,726, 4,589,996, 4,592,858, etc. The ferroelectric liquid crystals disclosed in these publications may be employed in the present invention.

More specifically, as ferroelectric liquid crystal compounds applicable to the present invention, decyloxybenzylidene-P'-amino-2-methylbutylcinnamate (DOBAMBC), hexyloxybenzylidene-P'-amino-2-chloropropylcinnamate (HOBACPC) and 4-o-(2-methyl)-butylresorcylidene-4'-octylaniline (MBRA8) may be mentioned.

In preparing a ferroelectric liquid crystal element using materials selected from among those mentioned above, the element may, if necessary, be supported by a copper block with an embedded heater or the like so as to maintain a temperature which will provide the SmC* or SmH*phase of the liquid crystal compound.

Further, apart from the above-described SmC* and SmH* phase liquid crystals, such ferroelectric liquid crystals as can be represented with the chiral smectic F, I, J, G or K phase may also be employed in this invention.

FIG. 4 schematically shows an example of the ferroelectric liquid crystal cell. Reference numerals 41a and 41b denote substrates (glass plates) coated with a transparent electrode such as In_2O_3, SnO_2, and ITO (indium-tin-oxide) between which an SmC* phase liquid crystal is enclosed in such a manner that the liquid crystal molecule layers 42 are arranged at right angles to the glass surfaces. The thick lines 43 denote liquid crystal molecules each having a dipole moment ($P\perp$) 44 perpendicular to the molecules. By applying voltage not less than a certain threshold between the electrodes on the substrates 41a and 41b, the spiral construction of the liquid crystal molecules 43 come undone and the

orientation of the liquid crystal molecules 43 can be changed in such a manner that dipole moments (P⊥) 44 are all directed in the direction of the electric field. The liquid crystal molecules 43 are of a long and narrow configuration and show index anisotropy in the major and minor axis directions. Therefore, it will be easily understood that by placing polarizers on both sides of the glass surfaces in a cross-nicol position, a liquid crystal optical modulation element having optical properties varying with voltage application polarities can be obtained. Further, when the liquid crystal cell is sufficiently thin (e.g. 1μ), the spiral construction of the liquid crystal molecule comes undone even when no electric field is applied thereto, its dipole moment Pa or Pb being directed either upwards (54a) or downwards (54b). When, as shown in FIG. 5, an electric field Ea or Eb not less than a certain threshold and having different polarities is imparted to such a cell for a predetermined period of time, the dipole moment is directed upwards 54a or downwards 54b with respect to the electric field vector of the electric field Ea or Eb, and in accordance with this change in direction, the liquid crystal molecules are oriented either in the first or second stable condition 53a or 53b.

Using such a ferroelectric liquid crystal as an optical modulation element has two merits: firstly, its response velocity is very high; and secondly, the orientation of liquid crystal molecules presents a bistability. The second merit may be explained referring to FIG. 5. Application of the electric field Ea causes the liquid crystal molecules to be oriented in the first stable condition 53a. In this condition, the stability is maintained even if the electric field is turned off. Further, application of the reverse electric field Eb causes the liquid crystal molecules to be oriented in the second stable condition 53b thereby changing the orientation of the molecules. The condition is also maintained in this case even if the electric field is turned off. Further, the molecules are maintained in their respective orientations as long as the electric field Ea remains below a certain threshold. For such a

high response velocity and bistability to be realized effectively, the cells should preferably be as thin as possible; generally, the suitable thickness thereof may be 0.5 to 20 μ, and especially 1 to 5 μ.

[Effect of the Invention]

As described above, by placing a conductive anisotropic adhesive composed of a thermosetting resin dispersedly containing conductor particles between the connection electrodes of a ferroelectric liquid crystal element and a film carrier tape and by connecting these components together by thermocompression bonding, a mounting structure can be obtained in which the connection resistance remains stable, irrespective of the re-orientation process temperature of the ferroelectric liquid crystal display element, thereby enhancing the reliability of such an element.

4. Brief Description of the drawings

FIG. 1 is a plan view of a connection structure in accordance with this invention. FIG. 2 is a sectional view of the same. FIG. 3(a) is a characteristic diagram showing the change in the re-orientation process temperature with time. FIG. 3(b) is a characteristic diagram showing the change in the connection resistance with time in a structure other than the present invention. FIG. 3(c) is a characteristic diagram showing the change in the connection resistance with time in this invention. FIGS. 4 and 5 are perspective views showing the ferroelectric liquid crystal element employed in this invention.

FIG. 1

12	FILM CARRIER TAPE
13	EXTERNAL CIRCUIT ELECTRODE
14	LIQUID CRYSTAL PANEL
15	EXTERNAL CIRCUIT CONNECTION ELECTRODE
141	SUBSTRATE

FIG. 2

11	ANISOTROPIC CONDUCTIVE ADHESIVE
12	FILM CARRIER TAPE
13	EXTERNAL CIRCUIT ELECTRODE
14	LIQUID CRYSTAL PANEL
16	HEAT TOOL
17	HEATING POWER SOURCE
18	IC
19	BONDING MEMBER
20	ADHESIVE
141	SUBSTRATE